Albedo and land surface temperature shift in hydrocarbon seepage potential area, case study in Miri Sarawak Malaysia.

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Abstract. The presence of hydrocarbon seepage is generally associated with rock or mineral alteration product exposures, and changes of soil properties which manifest with bare development and stress vegetation. This alters the surface thermodynamic properties, changes the energy balance related to the surface reflection, absorption and emission, and leads to shift in albedo and LST. Those phenomena may provide a guide for seepage detection which can be recognized inexpensively by remote sensing method. District of Miri is used for study area. Available topographic maps of Miri and LANDSAT ETM+ were used for boundary construction and determination albedo and LST. Three land use classification methods, namely fixed, supervised and NDVI base classifications were employed for this study. By the intensive land use classification and corresponding statistical comparison was found a clearly shift on albedo and land surface temperature between internal and external seepage potential area. The shift shows a regular pattern related to vegetation density or NDVI value. In the low vegetation density or low NDVI value, albedo of internal area turned to lower value than external area. Conversely in the high vegetation density or high NDVI value, albedo of internal area turned to higher value than external area. Land surface temperature of internal seepage potential was generally shifted to higher value than external area in all of land use classes. In dense vegetation area tend to shift the temperature more than poor vegetation area.

1. Introduction

Long term course of hydrocarbon seepage on material sediment and water alters mineralogical composition with corresponding change in chemical and physical properties of rocks and soils. This is indicated with change in colour, hardness, electric, magnetic and radioactive properties of minerals. At the surface this is indicated with alteration product exposures, change in fertilities rank soils and vegetation manifest, bare development and stress vegetations [1-3]. In the remote sensing side, those things relate with change in refection, absorption and emission properties toward the light or radio magnetic energy. The change of vegetation density alters the reflectivity and absorption properties accompanied with change in albedo. This leads to change radiative transfer and convective overturning energy [4], changes of the surface thermodynamic properties and change in emissivity which indicated by change in LST [5]. Briefly, there should have different properties of visible and thermal spectral response which leads to shift in albedo and LST between hydrocarbon seep infected with non infected land area [6-10].

The objective of study is to detect hydrocarbon seepage in onshore area through the investigation of the influence of the seepage existence on land surface albedo and land surface temperature. This study is therefore works in the two spectral regions namely visible to near infrared range for determination on albedo, and thermal infrared range for determination of land surface temperature.

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Finally, this study is expected to contribute to low cost detection of hydrocarbon seepage in tropical onshore area.

2. Study area

District of Miri, Serawak state of Malaysia is used for study area. This area known is the part of North West Borneo petroleum province. District of Miri is a mature onshore oil and offshore gas field. Although the Miri onshore field had not producing oil anymore, however this area is still potentially having some hydrocarbon seepage due to existing petroleum system. District of Miri is actually an urban area, located in the tropical region with the complex land cover system around the city (see Figure 1).

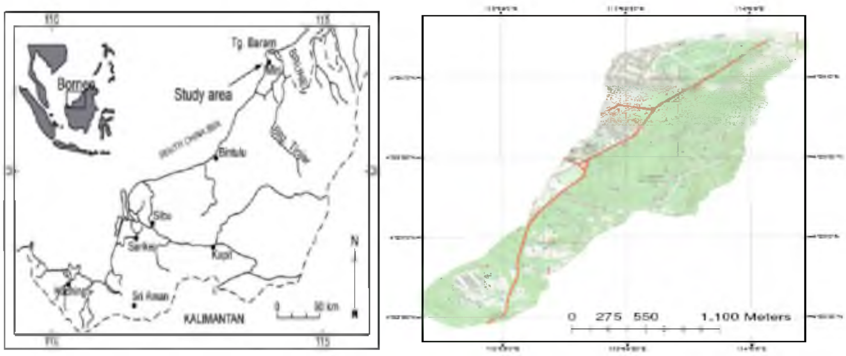

Figure 1. District of Miri and seepage potential area.

Topographic map of Miri study area was also prepared. This includes the map of abandoned oil field. The map is used as a reference for making the boundary of internal and external seepage potential. The boundary is constructed by linking line of all outer part of oil well marks in this abandoned field (see Figure 1). The internal boundary is called internal seepage potential area covers a complex mixture of urban area and tropical land cover system, which include bare area, farm, plantation and forest area as well as the external boundary.

3. Methodology

Decreasing of vegetation density or stress vegetation caused by any process including hydrocarbon seepage, increases surface albedo. This leads to loose of radiative transfer and reducing of convective overturning energy at the surface [4], accompanied with lower emissivity and increase in LST. On the hands, hydrocarbon eventually mixes with the surface material such as soils caused the intrinsic change in thermodynamic properties of those materials, manifested with another change in emissivity and corresponding change in LST [5]. The change reflectivity and absorption properties doe to decreasing vegetation density or stress vegetation, and change surface thermodynamic properties due to hydrocarbon mixed surface materials, role together for further change in albedo and LST, whether increase or decrease. Those phenomena play for any land cover types, but in case of hydrocarbon mixed surface materials is more obviously in the bare area.

Base on the above reason, it is believed that hydrocarbon infected area should have a different albedo and LST compare to non infected area. This study is therefore targeted to investigate of albedo and LST differences between internal and external seepage potential area. In this study, albedo was derived from reflectance of visible to near infrared band according to Liang [4], while LST derived from radiance of thermal band of LANDSAT ETM+ according to Zhang et.al [11] and Tan et.al.[12]. This study is performed according to the stepwise as shown in Figure 2. It comprises of data preparation, determination of basic parameters, land use classification and statistical comparison analysis.

3.1. Data preparation

This study was used a clearly, cloud free image, LANDSAT ETM+ observed on July 10^{th}, 2001. Atmospheric correction for visible to near infrared was performed by FLAASH of atcor application available in ENVI. Thermal actor application available in ENVI was also used for atmospheric

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correction of thermal band of LANDSAT ETM+. The image after FLAASH atmospheric correction loaded in ENVI true colour shows in Figure 2.

The basic parameters required to determine the potential hydrocarbon seepage area are albedo and LST. One additional parameter, NDVI was required for LST determination and land use classification. NDVI was determined by vegetation analysis application available in ENVI. Figure 3 shows determined NDVI for Miri.

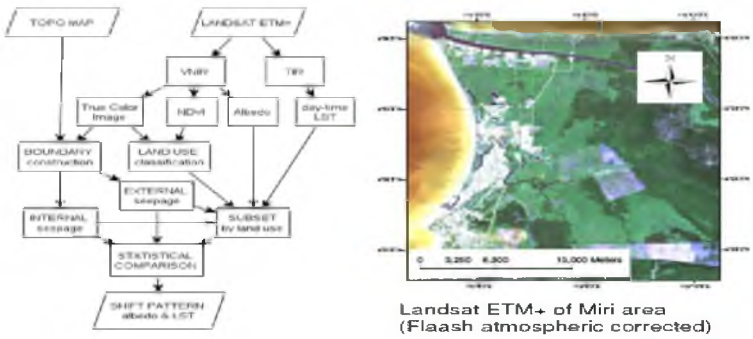

Figure 2. Albedo and LST shift investigation model, and LANDSAT ETM+ of Miri.

3.1.1. Surface albedo . Surface albedo was obtained by weighting the spectral reflectivity of visible to near infrared bands. Weighting factor are adopted from the simulation values. According to Liang [4], the surface albedo can be expressed according as the following equation:

$$A = 0.356 \propto_1 + 0.130 \propto_3 + 0.373 \propto_4 + 0.085 \propto_5 + 0.072 \propto_7 - 0.0018 \quad (1)$$

Where $\propto_i$ spectral reflectance of band i. Figure 3 shows the resulted surface albedo map of Miri.

3.1.2. Land surface temperature (LST). Land surface temperature was determined from spectral radiance of thermal band of LANDSAT ETM. Figure 3 shows of determined LST map of Miri. According to Zhang et.al. [11] and Tan et.al [12], LST can be performed with the following equation [11]:

$$T_B = \frac{K_2}{ln\left(\frac{K_1}{L_\lambda}+1\right)} \quad (2)$$

$$S_t = \frac{T_B}{1+\left(\lambda\frac{T_B}{\rho}\right)ln\varepsilon} \quad (3)$$

where,
L_λ = spectral radiance
T_B = brightness temperature (K)
S_t = land surface temperature (K)
K_1 = 666.09 $Wm^{-2}sr^{-1}\mu m^{-1}$
K_2 = 1282.71 K
λ = 11.457 μm
ρ = 1.438x10-4 mK
ε = emissivity

Emissivity can be derived using the following equation [12]:

$$\varepsilon_v = \varepsilon_v P_v + \varepsilon_s(1 - P_v) + d\varepsilon \quad (4)$$

where,
ε_v = Vegetation emissivity
ε_s = Soil emissivity
P_v = Proportion of vegetation.
$d\varepsilon$ = The effect of geometrical distribution of natural surface.

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Proportion of vegetation can be obtained by following equation [12],

$$P_v = \left|\frac{NDVI-NDVI_{min}}{NDVI_{max}-NDVI_{min}}\right|^2 \quad (5)$$

where,
$NDVI_{min}$ = 0.2
$NDVI_{max}$= 0.5

The effect of geometrical distribution of natural surface approximated by following equation [12],

$$d\varepsilon = (1-\varepsilon_s)(1-P_v)F\varepsilon_v \quad (4)$$

This study used ε_v = 0.99 as a dense vegetation and ε_s = 0.97 as a bare area [12]. The shape factor, *F*, which is the mean value for different geometrical distribution is assumed with a value of 0.55 [13].

3.2. Land use classification

Three kind of land use/cover classification methods were applied in this study which then applied for set up ROI of each unit of land use/cover that will be examined of their differences, as the follows:

3.2.1. Fixed classification method. This was performed by manually digitized or drawn on specific area that most represent the specific land use/cover class at the external area. There was no basic value employed except classified by normal eyes to distinguish land use unit on the true colour image. This method was applied for external seepage potential area. In this fixed classification method was performed for five classes which clearly different of land use type, namely (1) farm area, (2) bare area, (3) town area, (4) forest area, and (5) plantation area. Each class was made in almost the same size with the total internal seepage potential area.

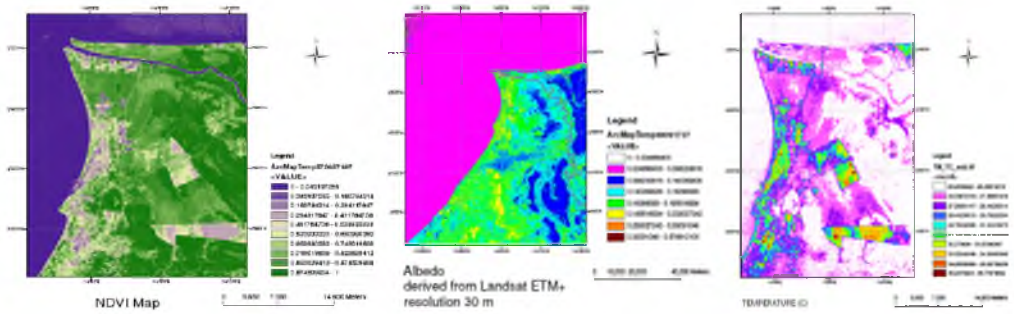


Figure 3. Basic parameters, NDVI, albedo and LST.

3.2.2. Supervised classification method. In this case, it was used ERDAS supervised classification with multiple training samples. This method was applied because the internal seepage area is too narrow to use for fixed classification method. The product of supervised classification comprised of five classes similar fixed classification. This because training samples were performed in the similar ways which base on the clearly unit in the limited range of visible normal eyes. Actually supervised classification can be used for internal and external seepage potential area, but the lack of this method could not further detail classifications.

3.2.3. Classification base on NDVI. The classification of each unit land use/cover is based on a specific range of NDVI value. This method was used for further detail of land use/cover classification; and it can be used consistently either for internal and external seepage potential area. The NDVI land use classification is having the advantage on the ability for further detail classification to any number of classes [14-16]. Previous implementation of this classification was reported to reach of 72% accuracy [14]. It was better suited for large area which predominantly of vegetation [15].

This classification was used consistently for internal and external seepage potential area. In this case, study area was divided into seven classes, namely (1) town for NDVI range of 0.1158 to 0.2316, (2) bare-town for NDVI of 0.2316 to 0.3474, (3) bare (look like dry clay) for NDVI of 0.3474 to 0.4632, (4) bare-soil (look like wet soil) for NDVI of 0.4632 to 0.5790, (5) grass-farm (looks populated from grass to farm) for NDVI of 0.5790 to 0.6948, (6) plantation for NDVI of 0.6948 to

0.8105, and (7) forest for NDVI of 0.8105 to 0.9263. In this investigation, the important thing is not the attribute of classes (the name of class is not important), but the class should contain absolutely same object between internal and external seepage for comparison purpose.

3.3. Statistical comparison
The study is focusing on the statistical comparison analysis of albedo and LST between internal seepage potential area and external area for each land use. In this stage all parameters namely NDVI, albedo and LST were separated into corresponding land use/cover types.

At the beginning, there was no suggestion which direction albedo changes to the presence of hydrocarbon seepage. However, another study reported that lower vegetation density or vegetation stress generally associates with increasing in albedo. This allows to expecting that the internal seepage area will have higher albedo then external seepage potential area. For land surface temperature, there is a hypothesis that in the area which hydrocarbon exist will have higher LST than the surrounding area which no hydrocarbon seepage.

4. Results
The following statistical comparison of albedo and LST were resulted from two groups, namely the first one was result from combine of supervised classification for internal and fixed classification for external seepage potential area, the second one was result from land use classifications base on NDVI.

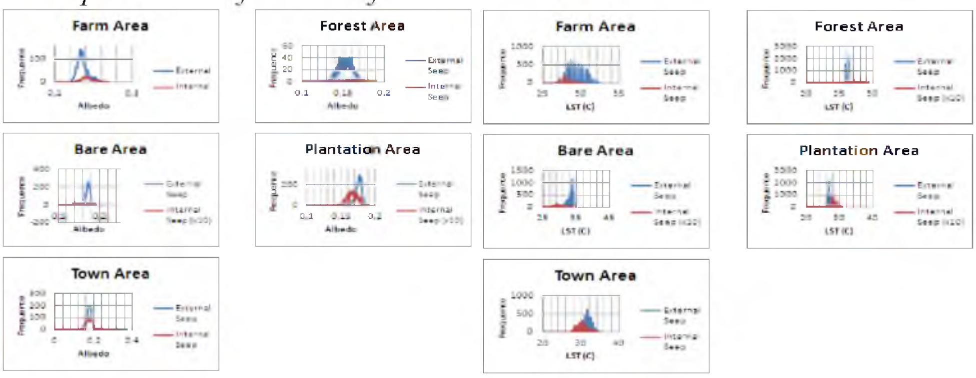
4.1. Combine supervised and fixed classification method


Figure 4. Statistical comparison on albedo and LST by combined fixed and supervised classification.

4.1.1. Albedo. In comparison to the albedo of external seepage potential area, the albedo of the internal area for farm area is positively shifted. In the forest area the albedo value for the internal seepage area is slightly larger as compared to the external reference area. This is shown by a slight shift of the albedo peak in the positive direction. Conversely, the peak of albedo for plantation area was clearly negative shifted, while for bare and town area were not clearly but tend to negatively shifted (see Figure 4).

The result was show that internal seepage potential area definitely shifted on albedo compare to external seepage area. The positive shift of farm and forest area were relevant with the expected shifting because the existence of hydrocarbon may develop bare land and stress vegetation which associates with increasing albedo. The slightly negative shift of bare and town area are caused by mixed hydrocarbon with surface material leads to reduce to reflectivity and corresponding reducing in albedo. Thereby, the positive shift of plantation area is not clear what the reason. Due to the shifting of plantation area, there was not clearly relation between the vegetation densities with shifting tendency.

4.1.2. Land surface temperature. The comparison of land surface temperature (LST) between internal and external seepage potential area shows that forest, plantation area LST were slightly positive shifted while farm, bare and town area negative shifted. Bare are was strongest negative shifted (see Figure 4).

The result was shows that hydrocarbon infected area definitely different in LST compare to uninfected area. The forest and plantation area were show positive shift, mean have higher LST. This relevant with expected shifting because the presence hydrocarbon may causing stress vegetation and bare development of land accompanied with higher LST. In the bare and town area were negative shift because mixed hydrocarbon with surface material. However the result of farm area was not clearly why negative shift. This actually expected that all vegetated area will shift to higher LST and bare area shift to lower LST, but farm area was not shift to higher LST. This was unclear what the reason. The result was also no relation of shifting tendency toward vegetation densities due to the shifting of farm area.

The above results show that there were clearly differences on albedo and LST between internal compare to external seepage potential area. This is congruent the hypothesis that the hydrocarbon infected area should have a different spectral respond toward the presence of hydrocarbon seepage. By the shifting of farm area then results were not clearly relation between vegetation density with albedo and LST shifting tendency.

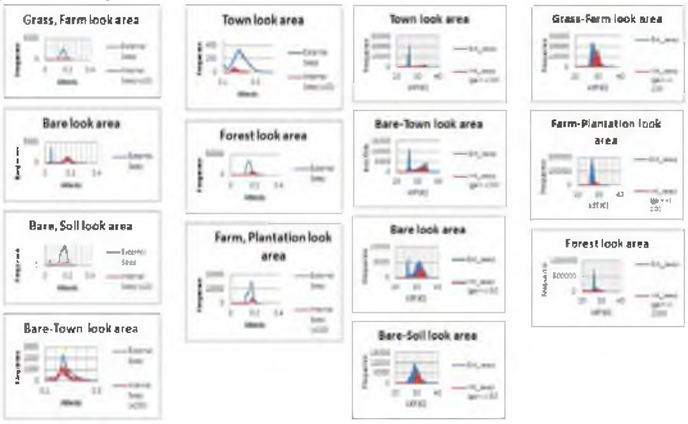


Figure 5. Statistical comparison on albedo and LST by classification base on NDVI.

4.2. Classification base on NDVI

The following statistical comparison of albedo and LST were resulted from land use classification base on NDVI value which was employed in either internal or external seepage potential area.

4.2.1. Albedo. The statistical comparison on albedo was show that forest look area was strongly positive shifted while town look area strongly negative shifted. Grass-farm and farm-plant look area were slightly negative shifted while bare-town slightly negative shifted. Bare and bare-soil look area were almost the same (see Figure 5).

This clearly indicated that the high NDVI value or dense vegetation area of internal seepage potential area has higher albedo than to external area. Conversely, the low NDVI value or poor vegetation area of internal seepage potential area has lower albedo than external area. The quantity of change in albedo is depend on the change in NDVI value. Higher NDVI accompanied with much higher increasing in albedo, while lower NDVI value accompanied with much lower decreasing in albedo.

4.2.2. Land surface temperature. The statistical comparison on LST was shows that all the classes were positive shifted, except bare-town look was unclearly shifted. Farm-plantation and forest look area were strongly positive shifted while grass-farm, bare-soil, and town look area were slightly positive shifted. (see Figure 5). This results were congruent with the hypothesis that hydrocarbon infected area should be have higher temperature. Although denser vegetation areas were lower temperature than bare area, but the incremental temperature due to the presence of hydrocarbon is higher than bare area.

5. Conclusion

The statistical comparison analysis between internal and external seepage potential area in all land use classes were generally found the shift on albedo and LST. In the land use classified by combine supervised and fixed classification method were unclearly show the pattern of shifting tendency related to vegetation density. Conversely, in the land use classified by NDVI range value, were show a clearly pattern of shifting tendency related vegetation density.

The pattern of shifting tendency shows that in the low vegetation density, albedo of internal seepage area turned to lower value than external area. Conversely in high vegetation density, albedo of internal area turned to higher value than external area. Land surface temperature of internal seepage area generally shifted to higher value than external area. Higher vegetation density tends to shift more than lower vegetation density.

The above shifting pattern was relevant with the suggestion that in poor vegetation or bare area hydrocarbon mixed surface material occurred caused reduce surface reflectivity accompanied with decreasing in albedo. Conversely, in dense vegetation area, hydrocarbon caused stress vegetation and bare development increases the reflectivity accompanied with increasing albedo. In the bare area, hydrocarbon mixed surface material caused change in surface thermodynamic property and slightly increases of emissivity accompanied slightly increases LST. In dense vegetation area, hydrocarbon caused stress vegetation and bare development accompanied with strongly increase in LST.

References

[1] Abrams M A 2005 Marine and Petroleum Geology **22** 457-477

[2] Everett J. R., Staskowski R. J., and Christopher Jengo 2002 World Oil 223 (11), Feature Article.

[3] Van der Meer, Freek, 2002 Terra Nova **14** 1-17

[4] Liang S 2000 72 213-238

[5] Ud din S., Al Dousari A., Literathy P 2008 *Journal of Environmental Management* 86 605-615

[6] Foudan Saleh, Menas Kafatos, Tarek El-Ghazawi, Richard Gomez and Ruixin Yang 2005 *International Journal of Remote Sensing* **26** 811-821

[7] Majumdar T.J. 2003 *International Journal of Remote Sensing* **24** 2207-2220

[8] Mitra D.S., Varadarajan K., Majumdar T. J., Kamat D. S. 1985 *International Journal of Remote Sensing* 6 (3 and 4) 497-506

[9] Nasipuri P., Mitra D.S., Majumdar T.J. 2005 *International Journal of Applied Earth Observation and Geoinformation* **7** 129-139

[10] Nasipuri P., Majumdar T.J., Mitra D.S. 2006 ActaAstronautica **58** 270-278

[11] Zhang Z, Ji M., Shu J. Deng Z., Wu Y 2008 *International Archieve of Photogrammetry, Remote Sensing and Spatial Information Sciences Vol XXXVII, Part 88, Beijing* 2008 601-606

[12] Tan KC, Lim H.S., Matjafri M.Z., Abdullah K 2010 *American Journal of Applied Sciences* **7** 5 717-723

[13] Sobrino J.A.,Juan C., Jimenez-Murioz, Paolini, *Remote Sengsing Environment* 90 434-440

[14] Feng Y. Xiao_bing L., Hong W., Hong_Jing Y. Yun_hao C 2005 Chinese *Journal of Plant Ecology* **29** 934-944

[15] Bose A.S.C, Viswanadh G.K., Giridhar M.V.S.S., and P. Sridhar 2012 *XIX International Conference on Water Resource, University of Illiniois, June 2012*

[16] Nyamekye 2010 Thesis Kwame Nkrumah University of Science and Technology, April 2010